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AN EVALUATION OF THE APPLICABILITY OF THE MILITARY INSTALLATION--ETC(U)
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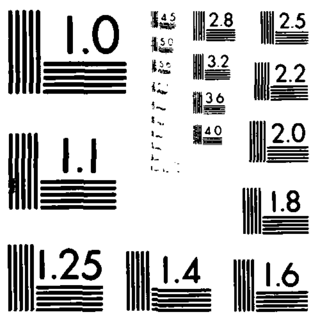

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TECHNICAL REPORT N-120
November 1981

AD A109698

AN EVALUATION OF THE APPLICABILITY OF THE MILITARY INSTALLATION WATER REUSE MODEL TO CIVIL WORKS ACTIVITIES

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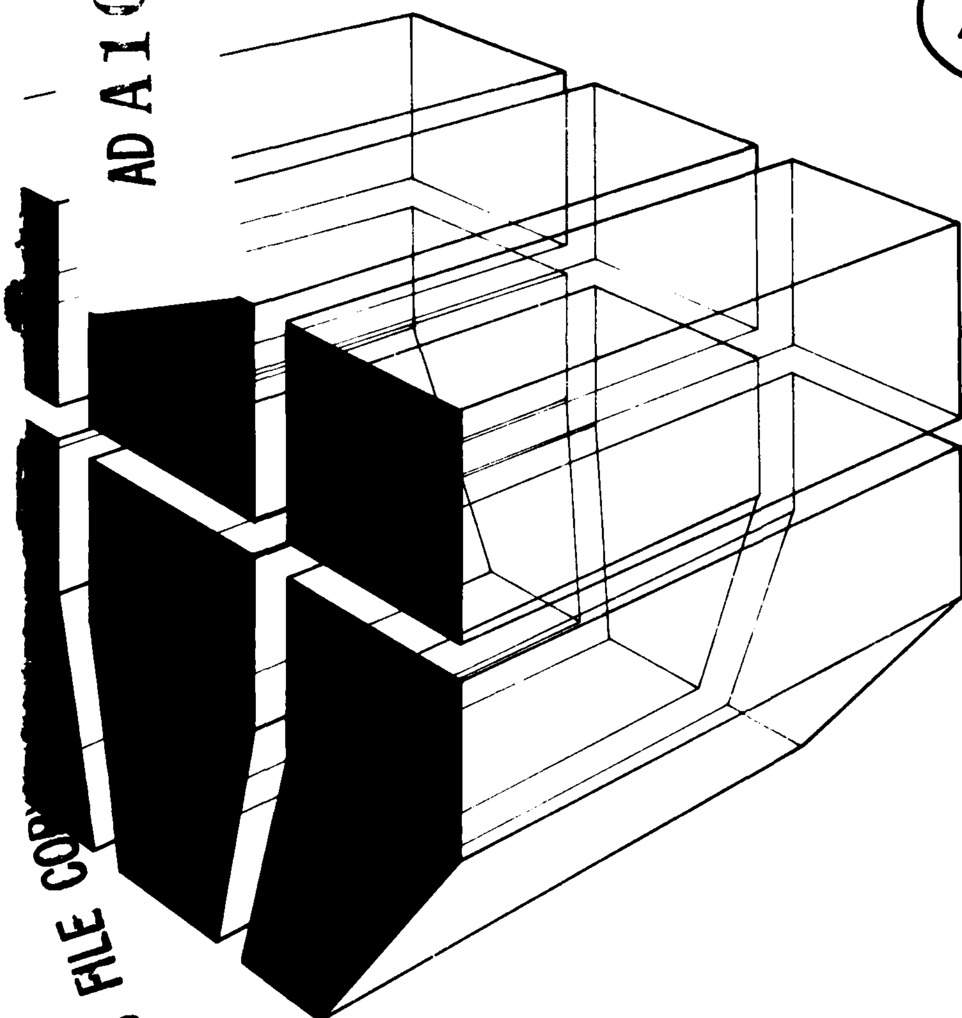

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This report examines whether a military subpotable wastewater reuse model can be applied to Civil Works water supply and water conservation planning procedures. These procedures, as detailed in Institute for Water Resources (IWR) publications, are compared to military reuse model procedures with respect to (1) type and level of data gathered, (2) criteria for the evaluation of reuse and conservation technology, and (3) type of economic analysis performed. It was concluded that:

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(1) An unmodified military model would apply to Civil Works projects when (a) they were similar to a military installation in scale and type of water-using activities, (b) water supplier billing studies were available for the project area, and (c) there were unexploited opportunities for industrial and agricultural recycle and reuse.

(2) Civil works projects of a different scale and nature than those usually found on military installations could use the military model if it was modified to (a) evaluate all costs and benefits of concern to Civil Works planners, and (b) consider conservation as well as recycle and reuse.

FOREWORD

This investigation was performed for the Directorate of Civil Works, Office of the Chief of Engineers (OCE), under Project CWIS 31735, "An Evaluation of the Applicability of the Military Installation Water Reuse Model to Civil Works Activities." The OCE Technical Monitor was Mr. Jim Ballif, DAEN-CWE-BU.

This investigation was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). Technical assistance and advice were provided by Mr. Kyle Shilling, Chief of the Policy Studies Division of the Institute for Water Resources (IWR). Dr. R. K. Jain is Chief of EN.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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CONTENTS

AN EVALUATION OF THE APPLICABILITY OF THE MILITARY INSTALLATION WATER REUSE MODEL TO CIVIL WORKS ACTIVITIES

1 INTRODUCTION

Background

During fiscal year (FY) 1980, *The Principles and Standards for Planning Water and Related Land Resources* of the U.S. Water Resources Council, as reported in the Federal Register, were revised to include water conservation and reuse considerations. Now when a new municipal and industrial water supply project is proposed by the Corps of Engineers, "water conservation shall be fully integrated into project and program planning and review as a means of achieving both the NED [National Economic Development] and EQ [Environmental Quality] objectives . . . at least one primarily nonstructural plan will be prepared and included as one alternative whenever structural project or program alternatives are considered."[1] These plans are used to determine whether it is feasible to meet all or part of a study region's water needs by improved conservation rather than by reservoir construction.

As part of an effort to develop effective methods of making the planning studies mandated by the U.S. Water Resources Council and of doing the subsequent estimates of a community's ability to increase its effective water supply through conservation, the Directorate of Civil Works, Office of the Chief of Engineers (OCE), asked the U.S. Army Construction Engineering Research Laboratory (CERL) to evaluate the applicability of a military water reuse model to Civil Works activities.

Objective

The objective of this study was to determine the applicability of a water reuse model developed for military installations to the analysis of water conservation opportunities within Civil Works planning regions.

Approach

1. The problem was discussed with Mr. Kyle Shilling, Chief of the Policy Studies Division of the Institute for Water Resources (IWR) and a member of the Directorate of Civil Works Water Conservation Committee. These discussions, plus a literature review, helped determine Civil Works needs for water conservation and reuse planning tools. The results of the discussions and literature review, and a description of the military reuse model, are presented in Chapter 2.

2. CERL then considered (a) whether an unmodified military model could be applied to a Civil Works planning region, and (b) modifications that would enhance the model's potential applicability to Civil Works studies. These results are presented in Chapter 3.

Mode of Technology Transfer

This report is the technology transfer document for this work.

2 PROCEDURE

Description of Military Reuse Model

The subpotable wastewater reuse model was first developed as a computerized system in 1974 for the Air Force by SCS Engineers of Long Beach, CA.[2] The purpose of the model was to provide a tool to help Air Force planners determine the cost-effectiveness of cascade water reuse at each of their fixed facilities. In cascade water reuse, the wastewater from one process is used as the water supply to another process which can use poor quality water. Some degree of wastewater treatment may occur between uses. The Air Force used the model to do preliminary design and costing for reuse networks at several of its installations, including McClellan Air Force Base (AFB) in Sacramento, CA.

In 1979, the U.S. Army Medical and Biomedical Research and Development Laboratory (USAMBRDL) asked SCS Engineers to modify the model for use at Army fixed facilities. A telephone survey of fixed facilities in the continental United

[1] *Procedures for Evaluation of National Economic Development Benefits and Costs in Water Resources Planning*, Federal Register 44FR72894 (Federal Register, 14 December 1979).

[2] *Cascade System for Water Reuse at Air Force Installations*, Contract Report No. F 29601-75-C-0019 (U.S. Air Force, October 1976).

States (CONUS) identified 19 water-using activities typically found at Army installations (Tables 1, 2, and 3). These activities were characterized with respect to typical water use, typical effluent quality, and tolerable influent quality.[3]

In 1980, the Army version of the reuse model was field tested at White Sands Missile Range, NM, by CERL and the Army Environmental Hygiene Agency (AEHA). The Army version of the military water reuse model is a manual process which uses the same data and algorithms found in the Air Force computer program.[4] This reuse model was designed for military installations; most military installations are similar to small cities in the types of commercial, industrial, and residential activities found there. The model is arranged in three distinct stages, so installations with very few or no reuse opportunities are identified before a large amount of data is gathered.

Stage One

The first stage is a protocol for quickly assessing installation reuse potential during a 1-day site visit. Virtually all of the data needed to complete the protocol are in records kept at the Facility Engineer and master planning offices.

Information required by the protocol includes:

1. *Present and future water supply*. This includes cost, availability, monthly usage levels (minimum, average, and maximum), and available alternative sources.

2. *Wastewater management*. This includes treatment facilities, effluent quality, National Pollutant Discharge Elimination System (NPDES) requirements, monthly volumes generated (minimum, average, maximum), and cost.

3. *Water laws or agreements*. This includes laws or agreements that may constrain reductions in water use or effluent discharged; it also includes any applicable ground water protection laws or regulations.

4. *Conservation methods*. This includes the types and amounts of reuse, recycling, or conservation already being practiced.

5. *Climatic factors*. This includes any climatic factors that influence water use and wastewater generation. These preliminary data are then used to decide whether the installation could benefit from wastewater reuse. Several criteria are suggested for making this decision, but ultimately the model user must use his her own judgment.

For example:

1. If a water supply is not available from a reliable, adequate, and inexpensive source currently or in the near future, reuse options should be pursued.

2. If additional treatment facilities for either water or wastewater are going to be necessary, reuse may be more economical. Both a high volume of wastewater and a good quality effluent contribute to the cost effectiveness of reuse.

3. If NPDES permit requirements are not being met, consumptive uses for the wastewater often can be found. High water consumption, especially if it occurs mainly during the warm months of the year, usually means there may be a high demand for irrigation or evaporative cooling. Both of these activities are very good sinks for reclaimed wastewater. The total volume of wastewater could also be reduced to eliminate sewage treatment plant (STP) overloading.

4. If an installation is committed by prior agreements or by law to specific volumes of water use and wastewater discharge, reuse may not be feasible.

5. If a high percentage of water or wastewater reuse is already being implemented, it is possible that most of the opportunities for reuse have already been exploited.

Stage Two

The second stage of the model requires another 1 to 2 days on-site to develop information concerning the spatial relationships and estimated water use and wastewater discharge of the major water-using activities on the installation. The data needed for Stage Two are:

1. *Spatial relationships*. To determine spatial relationships an installation map must be obtained

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[3] Curtis J. Schmidt, E. V. Clements, and L. Hammer, *Subpotable Water Reuse at Army Fixed Installations: A Systems Approach*, Volumes 1 and 2 (SCS Engineers, August 1979).

[4] J. T. Bandy, M. Messenger, and E. D. Smith, *Procedure for Evaluating Subpotable Water Reuse Potential at Army Fixed Facilities*, Technical Report N-109 (U.S. Army Construction Engineering Research Laboratory [CERL], October 1981).

Table 1
Army Activities With Greatest Potential as Sources of Reclaimed Water

Housing, Community, Protective, Administrative/Institutional, and Commercial*	Industrial	Wastewater Management
	Vehicle washracks	Sewage treatment plant effluent
	Aircraft washracks	Industrial waste treatment plant effluent
		Metal plating and finishing
		Cooling towers
		Dynamometers
		Industrial laundries
		Boilers

*The total sewage flow from these activities should be considered as one wastewater source.

Table 2
Army Activities With Greatest Potential as Users of Reclaimed Water

Community	Commercial	Industrial
Golf course irrigation	Laundry	Cooling towers
Landscape irrigation		Paint booth water walls
Athletic field, playground, park irrigation		Air pollution wet scrubbers
Recreational lakes and ponds		Autoclaves
		Dynamometers
		Vehicle washracks
		Aircraft washracks
		Steam cleaning
		Ash handling system water
		Maintenance washdowns

Table 3
Army Activities With Greatest Potential for Internal Recycling

Industrial Activities
Metal plating and finishing
Vehicle washracks
Aircraft washracks
Dynamometers
Large industrial autoclaves
Cooling towers
Paint booth water walls
Air pollution wet scrubbers

that shows elevations and is drawn to a scale of at least 1 inch = 500 feet (1 mm = 6 m). The individual(s) who seem most knowledgeable about the water and wastewater systems should be asked to point out the water-using activities; these locations are then marked on the map.

2. *Specific activity water usage data.* Because water is rarely metered on Army installations, accurate estimates of the water use of individual activities sometimes are not available from either the Facility Engineer's office or the activity's employees. However, every effort must be made to develop accurate usage and discharge estimates, including daily, weekly, and monthly usage patterns for each activity. Tables 1, 2, and 3 give the typical activity descriptions developed by SCS. Water usage, tolerable water quality, and effluent quality data for these activities are also available from SCS.[5] Note that these "typical value" data ae used only after all avenues of inquiry have been exhausted.

The data gathered during Stage 2 of the model are used to decide whether reuse is economically feasible. This decision considers the following factors:

1. Rough daily water balances for the installation as a whole are calculated to reflect both summer and winter usage patterns and any other unique seasonal patterns that may exist. Individual activity water balances are also calculated.

2. The availability of good sources and sinks for reclaimed water is determined. A good source of reclaimed water is characterized by high effluent volume, reliable flow, and low pollution load. Good potential users of reclaimed water use significant volumes (as compared to total installation use) on a regular basis, and can use influent water of lesser quality than the potable supply. The best users of reclaimed water are those that can use good secondary effluent; this is because secondary effluent is usually available and inexpensive to produce. Activities that can use filtered secondary effluent also have good potential for economical reuse because most secondary plants can be readily upgraded with filtration (although this is expensive).

3. If promising sources and sinks for reclaimed water are present on the installation, reuse networks are sketched out to route water from one activity to another. Information contained in the military reuse model can be used to develop a chart showing how suitable each activity's effluent is for use as influent to all of the other activities. Different levels of treatment can be considered. Figure 1 shows the suitability of reuse of effluent from installation housing, given various levels of treatment, with respect to 15 water quality parameters. The activity names are printed vertically; an "X" underneath the activity means the installation housing effluent could be reused in that activity, given the level of treatment specified, with respect to that pollutant. For example, the figure shows that for biochemical oxygen demand (BOD), secondary treatment would be adequate to reuse the installation housing effluent in the air pollution scrubbers, the paint booth water walls, for steam cleaning, or to irrigate the golf course. However, reverse osmosis would be necessary before it could be used in the boilers, the photo lab, or in electroplating operations.

4. Many small, scattered sources and users make it harder to implement reuse economically; however, when faced with high water supply or wastewater treatment costs and or inadequate or unreliable supply, reuse networks for these unpromising activities can be drawn and considered. This requires 1 or 2 days of office work. These networks are essentially schematic diagrams showing the distribution of fresh and reclaimed water throughout the installation, as well as the collection, treatment, reuse, and disposal of wastewaters.

5. After all possible cascade networks are drawn, a water balance is done on each network to size any necessary storage and treatment facilities. If seasonal variations are large, the balances are developed on both a monthly and daily basis: these balances include maximum and minimum days and months.

6. The amounts of materials, labor, and energy needed to implement and operate each network are estimated next. Construction and material costs for pipelines and storage facilities, including any necessary earthwork or concrete work, are obtained from the current Means *Building Construction Cost Data* or *The Dodge Guide to Public Works and Heavy Construction Costs.*[6] The head and discharge rates

[5] Curtis J. Schmidt, Ernest V. Clements, and LeAnne Hammer, *Subpotable Water Reuse at Army Fixed Installations: A Systems Approach*, Volumes I and II (SCS Engineers, August 1979).

[6] *Building Construction Cost Data*, 38th Annual Edition (Robert Snow Means Co., 1980); and *The 1980 Dodge Guide to Public Works and Heavy Construction Costs*, Annual Edition No. 12 (McGraw-Hill Information Systems Co., 1980).

SUITABILITY OF ACTIVITY EFFLUENT FOR REUSE

BASE: OVERLOAD ARMY BASE
ACTIVITY: BASE HOUSING
ACTIVITY CODE: HOUSE:
SPECIAL TREATMENT: NONE

NONE	BOIL	PHOTO	PLATE	IWR	HOUSE	SCRUB	PAINT	CLEAN	DYNA	GOLF
BOD										
COD										
PHNL				\		\	\	\	\	\
SS										
TDS			\	\	\	\	\	\	\	\
O&G	\			\		\	\	\	\	\
CL				\		\	\	\		\
NO3	\	\	\	\	\	\	\	\	\	\
NH4									\	
PO4	\	\	\	\	\	\	\	\	\	\
NA	\		\	\	\	\	\	\	\	\
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PRIMARY	BOIL	PHOTO	PLATE	IWR	HOUSE	SCRUB	PAINT	CLEAN	DYNA	GOLF
BOD										
COD										
PHNL				\		\	\	\	\	\
SS						\	\	\		
TDS			\	\	\	\	\	\	\	\
O&G	\			\		\	\	\	\	\
CL				\		\	\	\		\
NO3	\	\	\	\	\	\	\	\	\	\
NH4									\	
PO4	\	\	\	\	\	\	\	\	\	\
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PHNL	\			\		\	\	\	\	\
SS						\	\	\		\
TDS			\	\	\	\	\	\	\	\
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CL				\		\	\	\		\
NO3	\	\	\	\	\	\	\	\	\	\
NH4						\	\	\	\	\
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FILTRATION	BOIL	PHOTO	PLATE	IWR	HOUSE	SCRUB	PAINT	CLEAN	DYNA	GOLF
BOD				\		\	\	\	\	\
COD				\		\	\	\		\
PHNL	\			\		\	\	\	\	\
SS	\			\		\	\	\	\	\
TDS			\	\	\	\	\	\	\	\
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CL				\		\	\	\		\
NO3	\	\	\	\	\	\	\	\	\	\
NH4				\		\	\	\	\	\
PO4	\	\	\	\	\	\	\	\	\	\
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CARBON ADS	BOIL	PHOTO	PLATE	IWR	HOUSE	SCRUB	PAINT	CLEAN	DYNA	GOLF
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SS	\	\	\	\	\	\	\	\	\	\
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NO3	\	\	\	\	\	\	\	\	\	\
NH4	\	\	\	\	\	\	\	\	\	\
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PHNL	\			\		\	\	\	\	\
SS	\	\	\	\	\	\	\	\	\	\
TDS	\	\	\	\	\	\	\	\	\	\
O&G	\	\	\	\	\	\	\	\	\	\
CL	\	\	\	\	\	\	\	\	\	\
NO3	\	\	\	\	\	\	\	\	\	\
NH4	\	\	\	\	\	\	\	\	\	\
PO4	\	\	\	\	\	\	\	\	\	\
NA	\	\	\	\	\	\	\	\	\	\
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Figure 1. Suitability of activity effluent for reuse.

required of each pump are calculated, then general price estimates are obtained from a national manufacturer; an estimate of maintenance hours per year is also required. Electrical energy needed for pumping is calculated from the pump characteristic curve provided by the manufacturer. Any needed new treatment facilities are sized and costed using information provided by the Environmental Protection Agency (EPA) or the manufacturers of specific reuse or recycle technology.

7. The total estimated cost for the construction of each network is annualized over its expected lifetime at the appropriate interest rate, and added to calculated operation and maintenance (O&M) costs. These figures are compared to the value of the potable water and wastewater treatment savings engendered by each network. Those networks that are clearly not cost-effective are eliminated from further consideration.

Stage Three

The third stage of the model consists of a 1- to 2-week survey of actual wastewater flows and water quality parameters. Those activities for which recent and reliable data are available are not included in the wastewater survey. The data gathered here are used to refine the design and costing of equipment and processes for each reuse network that survived the second stage. The result of the third stage is a report similar to an architect engineer (A E) firm's feasibility study; the two or three most cost-effective networks are described and compared with each other and the current situation.

CERL used the reuse model described above to assess reuse potential at nine Army installations across the United States. Eight of the installations surveyed did not show enough potential savings to justify the expense of the third stage of analysis, so wastewater surveys were not performed. The remaining installation, White Sands Missile Range, was analyzed through all three stages of the model.

Civil Works Water Conservation Planning Procedures

The development of the Corps water conservation planning procedures is well documented in a series of reports published from April 1979 to June 1980.

An Annotated Bibliography on Water Conservation contains short reviews of both published and

unpublished water conservation literature in three major problem areas: technical effectiveness, cost effectiveness, and social acceptability of available water conservation devices and practices.[7] These reviews describe the objective(s) and methodology of each study reviewed, and summarize and appraise the findings.

The Role of Conservation in Water Supply Planning discusses the historical definitions of conservation, proposes a new definition to be used in Corps planning procedures, and suggests criteria for evaluating potential water conservation measures.[8] One chapter summarizes the effectiveness and economic efficiency of actual efforts to conserve water in domestic-commercial, industrial-manufacturing, and agricultural sectors. The preparation of model plans is recommended for field operating agencies charged with including water conservation planning in municipal and industrial (M&I) water supply project planning.

Most of the concepts developed in this second document were incorporated into Volumes 1 and 2 of *The Evaluation of Water Conservation for Municipal and Industrial Water Supply*.[9] Volume 1 outlines a proposed general approach to water conservation planning; Volume 2 shows the application of that approach to two case studies.

Figure 2, reprinted from Volume 1, outlines a general procedure for developing water conservation plans. According to Volume 1, water supply plans are developed first with no consideration of conservation opportunities. After potential water conservation measures are identified and described with respect to a number of stated criteria (e.g., technical feasibility and social acceptability), their effects on the NED and EQ benefits of each alternative water supply plan are evaluated.

[7]Duane D. Baumann, et al., *An Annotated Bibliography on Water Conservation*, Contract Report 79-3 (U.S. Army Institute for Water Resources, April 1979).

[8]Duane D. Baumann, et al., *The Role of Conservation in Water Supply Planning*, Contract Report 79-2 (U.S. Army Institute for Water Resources, April 1979).

[9]Duane D. Baumann, et al., *The Evaluation of Water Conservation for Municipal and Industrial Water Supply—Procedures Manual*, Contract Report 80-1 (U.S. Army Institute for Water Resources, April 1980); and Duane D. Baumann, et al., *The Evaluation of Water Conservation for Municipal and Industrial Water Supply—Illustrative Examples* (Army Institute for Water Resources, June 1980).

Volume 2 describes the application of this procedure to two case studies in the Atlanta, GA, and Tucson, AZ, metropolitan areas. Most of the information in this volume is relevant to assessing the applicability of the military reuse model to M&I water supply and conservation planning. The data gathered during the case studies are very similar to those needed for the reuse model, with one exception: the level of detail gathered on major water-using activities. A Civil Works M&I case study disaggregates water usage into four categories: domestic, industrial, commercial, and agricultural. The military reuse model works with the individual water-using facilities themselves; e.g., cooling towers, boilers, laundries, and vehicle washracks.

The actual data analysis performed by the military reuse model is much less detailed than the one suggested for Civil Works in Volume 1. Implementation costs and long- and short-run supply costs are calculated by the military reuse model. The other costs and benefits of interest to Civil Works activities are not considered. These include lost water user benefits, lost benefits to other purposes, external diseconomies, external economies, and foregone external diseconomies, as defined in Volume 1. The output from the military reuse model alone could not be used to determine the effect of water conservation and reuse on the NED and EQ objectives for a Civil Works project.

Discussion of Existing Tools

1. The Methodology for Areawide Planning Studies (MAPS) system has been developed by the U.S. Army Waterways Experiment Station (WES) to provide a uniform and centralized Corps procedure for designing and costing water supply projects.[10] The MAPS output is coordinated completely with the criteria specified by the Water Resources Council in its *Principles and Standards*, and those specified in Volume 1 of the report described above. The MAPS system is being modified to account for water conservation. The required inputs to the system include the peak and average flow with and without conservation. It does not predict potential water savings engendered by conservation.

[10]*Interim Guidance on Use of MAPS Computer Program for Water Supply and Conservation Studies*, Engineer Technical Letter (ETL) 1110-2-259 (Office of the Chief of Engineers [OCE], February 1981).

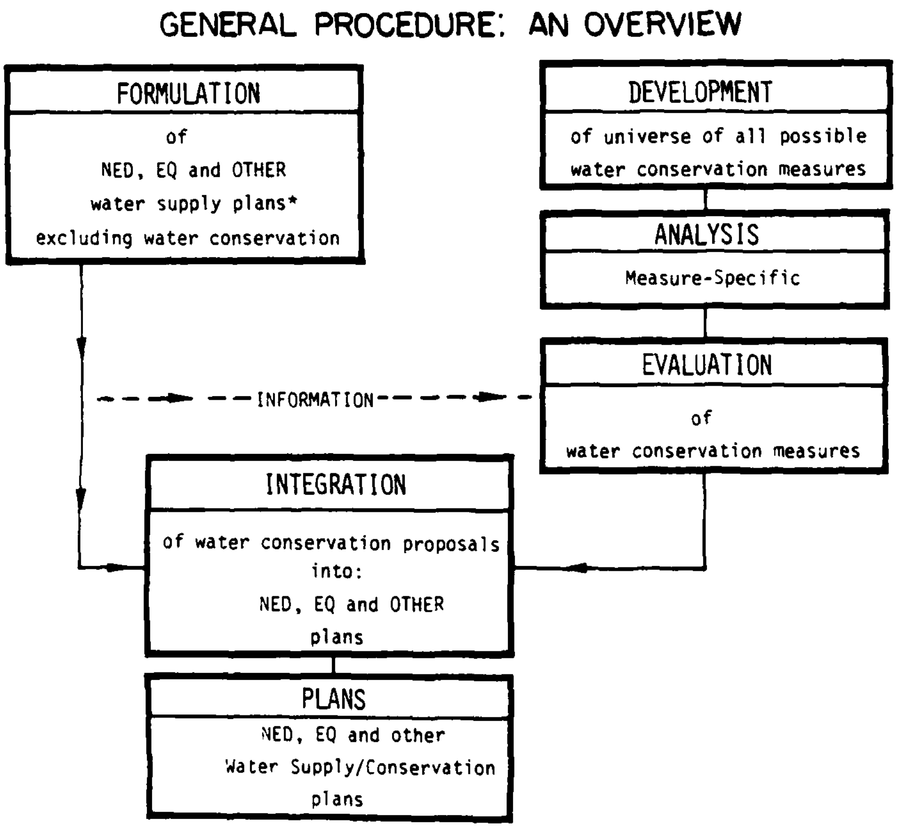

Figure 2. General procedure for developing water conservation plans (reprinted from Duane D. Baumann, *The Evaluation of Water Conservation for Municipal and Industrial Water Supply—Procedures Manual*, Contract Report 80-1 [U.S. Army Institute for Water Resources, April 1980]).

2. A computer system has been designed at Southern Illinois University to evaluate the economic efficiency of recycling renovated wastewater into the potable water supply reservoir in times of drought or low water levels.[11]

3 RESULTS AND ANALYSIS

Application of Unmodified Military Model to Civil Works Water Conservation Planning Procedures

Several important factors affect the application of the military reuse model in its current form to Civil Works water conservation planning procedures. The first concerns what types of reuse and conservation should be emphasized as having more potential for significant water savings. This decision depends on an assessment of which types of reuse and conservation have already been implemented, and which have not.

Two opinions exist regarding approaches to such water conservation studies. One emphasizes any water conservation planning which focuses on domestic conservation; opportunities for other types of reuse and conservation are considered insignificant. Within this perspective, information on industrial reuse options contained in the military model would have very little practical application to Civil Works water supply projects because (1) most industrial users are self-supplied, so their usage would not be included in water supply project planning, and (2) industrial water withdrawals have decreased greatly over the past decade, since more and more industries are finding it cheaper to reuse or recycle their process and cooling water than to treat it to the level required by their NPDES discharge permits.

The second opinion is best expressed in *The Role of Conservation in Water Supply Planning*. As noted in Chapter 2, this document assesses the amount of conservation already implemented by the various water using sectors. It references the National Water Assessment which shows that industrial water withdrawals have been decreasing. Specifically, this document states:

> Upon first inspection, the greatest potential for savings in water use from the application of water conservation measures would seem to be in the agricultural sector. However, according to the U.S. Water Resources Council (1978), the potential for the greatest reduction in withdrawal use lies in the manufacturing sector: withdrawals of water for manufacturing purposes are expected to decline by the year 2000 to only 19.7 bgd or from 15 percent of the national total to only 6 percent. Water use in irrigation and steam-powered generation are expected to remain relatively unchanged. The U.S. Water Resources Council notes, however, that potential savings of water for irrigation could be 20 to 30 percent.[12]

Four factors must be considered when evaluating the applicability of the military reuse model to Civil Works activities.

1. The military reuse model was designed to address the question of subpotable wastewater reuse through the use of cascade networks. As such, it contains information on only a subset of water conservation alternatives. Specifically, agricultural and landscape irrigation are emphasized; domestic reuse is not considered. Conservation in the sense of "using less" to perform a specific activity is not considered at all.

2. A Civil Works planning region covers a great deal more territory than a military installation. For example, the Atlanta study described in Volume 2 of *The Evaluation of Water Conservation for Municipal and Industrial Water Supply* covers a seven-county region that includes 1.6 million people, 45 municipalities, and 96 wastewater treatment plants. In contrast, a typical military installation houses an effective population of less than 10,000 people, and is usually served by one water and one wastewater treatment plant that each treat less than 5 million gallons per day.

This difference in scale greatly complicates the problem that the reuse model was designed to solve. The number of possible networks for routing water from one use to another increases geometrically as the number of water users under consideration grows. In its current form, the military reuse model calls for (a) identifying the promising sources and sinks of reclaimed water, and (b) rough costing all

[11] *An Evaluation of Water Reuse for Municipal Supply*, IWR Contract Report 74-11 (U.S. Army Institute for Water Resources, December 1974).

[12] *The Nation's Water Resources, The Second National Assessment* (U.S. Water Resources Council, October 1977).

potential reuse networks that can be drawn among them. No mechanism exists for identifying those networks that could not possibly be cost-effective because they cover too great a physical distance, because this situation is rarely encountered on military installations. For Civil Works applications, it would be almost mandatory to derive the relationships among (a) the volume of reclaimed water delivered, (b) the distance and elevation over which it is pumped, (c) the diameter of pipe used, and (d) the cost of potable water. This would have to be done so a breakeven point could be defined to eliminate from consideration those networks that require an inordinate amount of pumping and piping.

3. The third factor to be considered is the level of detail of water usage data currently gathered for Civil Works planning studies. As mentioned in Chapter 2, Civil Works studies analyze four or five major water using sectors, while the military model separately analyzes each major user, regardless of sector. The *Revised Plan of Action for Water Conservation* recommends that water conservation research be coordinated among the different Corps agencies and laboratories; "... there is no intent to escalate the detail level of engineering information developed during this stage (design and construction). The water conservation review during this stage should be based on the engineering information customarily available for that stage."[13]

Even if this position should be changed and an attempt made to collect more detailed data, this would be a much more difficult problem in a Civil Works planning region than in the military situation. Army installations are well suited to providing the different levels and types of data called for by the military reuse model. Almost all of the records needed are kept either by the Facility Engineer or the Master Planner. Accurate and detailed maps showing the water distribution system, wastewater collection system, location of major water using activities, and elevations are also available. This type of centralized and detailed record-keeping is not done in most civilian communities. A study of the billing records of all of the water suppliers in the study region would be needed to gather data similar to that called for in the military reuse model. This type of study is expensive and time-consuming, even when the suppliers keep excellent records.

4. The evaluation criterion of social acceptability, which is so important in Civil Works studies, is not addressed by the military model. On a military installation, only one person, the installation commander, must be convinced that water reuse and conservation is a viable approach to water supply. In a civilian community, many diverse groups representing varying and often conflicting interests must be persuaded that water reuse and conservation are both technically feasible and cost effective. Even if this is done, the question of who should pay remains. Reuse schemes that are cost-effective when the the cost to the community as a whole is considered, such as those that make the construction of new treatment works necessary, may or may not be cost-effective for the specific activities that would have to implement reuse.

Potential Modifications to Military Model

The following changes would have to be made to the military reuse model in order to apply it to Civil Works studies:

1. A procedure would have to be developed to define the breakeven point among the volume of reclaimed water delivered, size of pipe necessary, distance and elevation of pumping, and cost of potable water. This procedure would eliminate grossly unprofitable networks from consideration before any costing is done.

2. It would be necessary to examine the five-sector water usage data collected for Civil Works case studies to determine what additional data would be needed to apply the military reuse model.

The following modifications would make the military model more useful to Civil Works studies:

1. A mechanism to evaluate all costs and benefits considered in a Civil Works study, instead of only implementation costs and supply costs.

2. Consideration of conservation as well as reuse and recycle opportunities.

[13] *Revised Plan of Action for Water Conservation* (Department of the Army, 8 May 1980).

4 CONCLUSIONS

The areas of applicability of the subpotable military reuse model to Civil Works water conservation planning procedures have been identified. Specifically, it is recommended that the military model be considered for use in water supply and conservation planning studies in the following situations:

1. When the Civil Works study region being considered is similar to a military installation in scale and type of water-using activities.

2. When water supplier billing studies are already available for the planning region.

3. When unexploited opportunities for industrial and agricultural recycle and reuse exist in the planning region.

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